Jurnal Geologi dan Sumberdaya Mineral Vol. 26 No. 1 Februari 2025 hal. 17-27

Geo-Science

Jurnal Geologi dan Sumberdaya Mineral
Journal of Geology and Mineral Resources
Center for Geological Survey, Geological Agency, Ministry of Energy and Mineral Resources
Journal homepage: http://jgsm.geologi.esdm.go.id
ISSN 0853 - 9634, e-ISSN 2549 - 4759

Analisis Spasial-Temporal Kerugian Perumahan Akibat Likuifaksi (Studi Kasus Gempa Palu Tahun 2018 di Balaroa, Petobo, dan Jono Oge)

Spatial-Temporal Analysis of Housing Losses Induced by Liquefaction (A Case Study of the 2018 Palu Earthquake in Balaroa, Petobo, and Jono Oge)

Muhammad Junaid dan Adi Wibowo

Universitas Indonesia, Jalan. Lingkar, Pondok Cina, Kecamatan Beji, Kota Depok, Jawa Barat 16424
email: muhammadjunaidk22@gmail.com dan wibowo.geoui@gmail.com

Naskah diterima: 28 Februari 2024, Revisi terakhir: 02 Februari 2025, Disetujui: 02 Februari 2025 Online:16 Februari 2025
DOI: http://dx.doi.org/10.33332/jgsm.geologi.v26i1.887

Abstrak- Gempa Palu tahun 2018 menyebabkan kerusakan parah pada wilayah metropolitan yang padat penduduk, karena ukurannya yang merusak dan tingginya kerentanan lokasi ini terhadap gangguan seismik. Fenomena ini telah banyak diteliti, dan para peneliti secara umum sepakat bahwa solusi perumahan yang tangguh dan integrasi teknologi geospasial mutakhir ke dalam pekerjaan manajemen bencana sangat penting. Tujuan Penelitian ini adalah memperkirakan jumlah penduduk terken dampak likuifaksi dengan data *Google Earth. Metode* yang digunakan adalah OBIA *(Object Base Interpretation Analysis*) yaitu mendeteksi bangunan rumah yang ada sebelum hilang akibat likuifaksi, kemudian menghitung jumlah penduduk dari jumlah bangunan yang hilang. Hasil temuan penelitian ini mengungkapkan kerugian perumahan yang signifikan di ketiga wilayah karena likuifaksi. Ketiga wilayah itu adalah Balaroa, Petobo dan Jono Oge. Petobo adalah wilayah yang mengalami perpindahan penduduk yang sangat mencolok. Hasil penelitian dapat memberikan uraian terperinci secara spasial tentang dampak likuifaksi pada area permukiman agar selanjutnya lingkungan perkotaan dapat beradaptasi terhadap peristiwa seismik. Hasil penelitian ini juga menujukkan bahwa perlu adanya integrasi langkah-langkah perencanaan perkotaan yang komprehensif. Sebagai kesimpulan, penelitian ini menggarisbawahi pentingnya strategi jangka pendek dan jangka panjang dalam manajemen bencana dan perencanaan perkotaan, yang menganjurkan pendekatan kolaboratif untuk membangun lanskap perkotaan yang tangguh, terutama di daerah yang rawan gempa bumi. Arah penelitian di masa mendatang disarankan, fokus pada penilaian kualitatif dan pengembangan kebijakan untuk meningkatkan infrastruktur yang tahan gempa.

Kata kunci: Data *Google Earth*, dampak likuifaksi, analisis spasial, kehilangan rumah, perpindahan penduduk

Abstract*-The 2018 Palu earthquake caused extensive damage to a densely populated metropolitan area due to its size and high vulnerability to seismic disturbances. This phenomenon has been widely studied, and researchers generally agree that resilient housing solutions and integrating advanced geospatial technologies into disaster management work are essential. This study aims to estimate the number of residents affected by liquefaction using Google Earth data. The method used is OBIA (Object Base Interpretation Analysis). It detects existing housing structures before they are lost due to liquefaction ,and then calculates the population from the number of lost structures. The findings of this study reveal significant housing losses in three areas due to liquefaction. The three areas are Balaroa, Petobo, and Jono Oge. Petobo is an area that has experienced a substantial population displacement. The study's results can provide a detailed spatial description of the impact of liquefaction on residential areas so that the urban environment can adapt to seismic events. The results of this study also show the need for a comprehensive integration of urban planning measures. In conclusion, this study underlines the importance of short-term and long-term strategies in disaster management and urban planning, advocating a collaborative approach to build resilient urban landscapes, especially in earthquake-prone areas. Future research directions are suggested, focusing on qualitative assessments and policy development to improve earthquake-resilient infrastructure.*

Keywords*: Google Earth data, liquefaction impacts, spatial analysis, home loss, population displacement*

INTRODUCTION

The Palu area saw significant changes due to the 2018 earthquake, especially in Jono Oge, Petobo, and Balaroa (Indonesian National Board for Disaster Management, 2018). This earthquake caused considerable destruction, especially in these heavily populated metropolitan areas, followed by tsunamis and soil liquefaction after the earthquake (Smith *et al.*, 2023). It is crucial to research the recognition of the pressing need to comprehend the spatial dynamics of these types of natural catastrophes (Jones & Taylor, 2019). Using the powerful capabilities of Google Earth Pro and ArcGIS, the research dives into a thorough geospatial analysis of house losses and population shifts in the wake of the earthquake .

This research incorporates geospatial techniques with government data to enhance the reliability of the analysis conducted. For instance, the government recorded a pre-earthquake population of 14,779 in Balaroa, and a spatial analysis estimated 14,800, which gave a difference of 0.14% (García-Ayllón *et al*., 2019). After the earthquake, however, the data showed more significant differences, with a latitude difference of 6.67% in this sub-district. These instances illustrate why incorporating other information sources is essential to justify using geospatial techniques (Zhang *et al.,* 2019).

The use of cutting-edge geospatial technologies has revolutionized catastrophe scenario research. Fernandez (2021) analyzes the use of remote sensing methods and Geographic Information Systems (GIS) in assessing earthquake-related losses. Nguyen and Patel (2022) build upon this notion, showcasing how geospatial methodologies can yield detailed insights into the spatial distribution of earthquake impacts. Zhou and Wang (2023) investigate the idea of spatial resilience, examining how the arrangement of metropolitan areas might either lessen or increase the negative consequences of natural catastrophes.

The devastation in Jono Oge, Petobo, and Balaroa necessitated an immediate review of urban resilience plans. The liquefaction phenomena, a rare yet catastrophic occurrence, led to the sinking and tilting of thousands of buildings, rendering many uninhabitable (Johnson & Lee, 2023). The quantification of housing losses, employing a combination of high-resolution satellite imagery and GIS spatial analysis to map the extent of the destruction, was used in the previous study, and the exploration of consequent population displacements and demographic changes, shedding light on the long-term impacts of the earthquake on local communities (Fernandez & Huang, 2023).

To support these findings, the population data measured by the government was cross-checked with the geographic estimate. For instance, Petobo had data from the government that recorded 20,234 people pre-earthquakes, and through spatial analysis, it was estimated that 20,150 people lived there, which was a mere 0.42% (Qiu *et al.*, 2022). When results were compared to official estimates obtained after the earthquake, it was observed that the slightly higher variation of 5.00% underscores the importance of horizontally validating spatial findings (Wardrop *et al.*, 2018).

Moreover, this research investigates the role of pre-existing urban planning and its effectiveness in mitigating such disasters. Previous studies have shown that the severity of damage could be significantly influenced by the urban layout, building standards, and the nature of land use before catastrophic events (Zhou & Wang, 2023). By incorporating land use data and historical urban development patterns, the study evaluates how the urban design of Balaroa, Petobo, and Jono Oge may have contributed to the scale of the disaster's impact (Kumar & Singh, 2023).

Furthermore, applying advanced geospatial tools, such as Google Earth Pro and ArcGIS, offers an innovative approach to disaster analysis. While ArcGIS enables complex spatial analysis and housing and population data modeling, Google Earth Pro provides an approachable platform for displaying the chronological course of urban changes (Garcia & Lopez, 2023). When used in tandem, these resources provide a thorough grasp of the spatial aspects of the catastrophe, paving the way for creating more intelligent and durable urban design techniques for future disaster relief (Williams & Davis, 2023). It is essential insight into the intricate interactions between urban environments and natural catastrophes through in-depth spatial analysis, laying the groundwork for constructing more resilient urban landscapes in seismically vulnerable areas (Nguyen *et al.*, 2023). In addition to recording and analyzing the immediate consequences of the Palu Earthquake, this project intends to contribute to disaster management and urban resilience.

This work contributes to the literature by assembling geospatial technology and a database of government information or prevalences, which grants a sound method to quantify housing loss and population changes. The differences, obtained by the comparative analyses, for example, comparing Jono Oge with pre-earthquake besides, average control, and end control measured at 0.57%, and with post-earthquake control evaluated to 10.00%, implying that integrating these techniques can enhance the exactness of the disaster management estimation.

METHOD

Study Area and Subjects.

The aerial pictorial in Figure 2 presents the areas affected by the 2018 Palu Earthquake in three subdistricts: Balaroa, Petobo, and Jono Oge, which all suffered due to soil liquefaction, mudflows, and fault displacement to varying degrees. The image focuses on critical features such as the road network, the irrigation system, and the Palu-Koro Fault, clearly depicting how earthquakes affect an area geographically. This study employs government data to corroborate the findings of the geospatial analysis of such regions. For instance, the government estimated that the population of Balaroa before the earthquake was 14,779; using spatial analysis, it was 14,800, with a difference of 0.14% (Atasoy & Kocaman, 2021). They did similar things but highlighted the importance of synchronizing spatial tools with record-keeping to develop sound disaster analysis (Nurul Fatma *et al.*, 2019). Figure 2 comprises four subfigures: (a) Overall maps of Palu City with the district, highlighting the important subdistricts and the Palu-Koro Fault line; (b) The Balaroa Subdistrict experienced extensive mudflows and displacement; (c) Petobo Subdistrict shows soil liquefaction and its impacts; (d) Jono Oge Subdistrict, which highlights similar impacts, although with additional vital installations. The mapping shows that geographical information systems have a role to play in disaster management strategies to build urban resilience. Geospatial mapping is a very effective means of vulnerability assessment and disaster planning regarding highly disaster-prone regions.

Earthquake impact as depicted in Figure 1, this study employs a methodological framework that shows geographical facets, Impact Evaluation, and Site Assessment, and Evaluation Approaches, carrying out analysis of earthquake shock assessment in detail.

Geographical Focus: This study component involves detailed mapping and in-depth analysis of regions ravaged by the earthquake. Special attention was given to densely populated areas with significant residential development. The site was selected because of its heightened vulnerability and the pronounced impact of seismic activities on densely inhabited urban settings (Garcia, L., 2020).

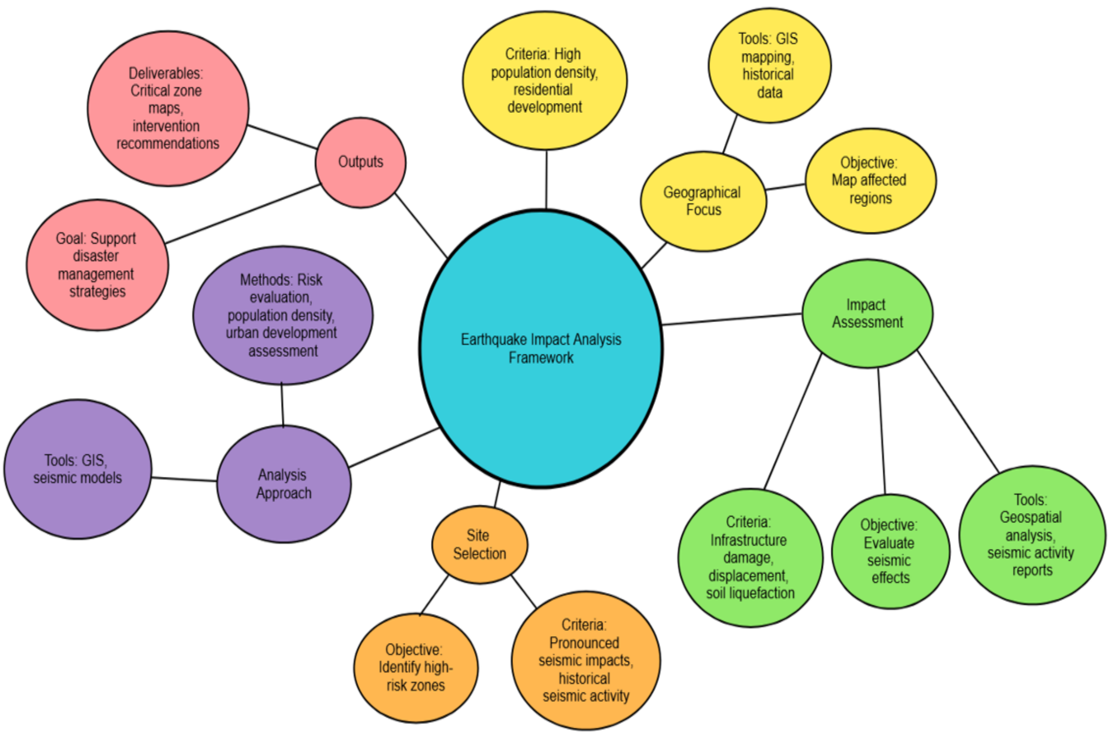

Figure 1. The framework of the Analysis of Earthquake

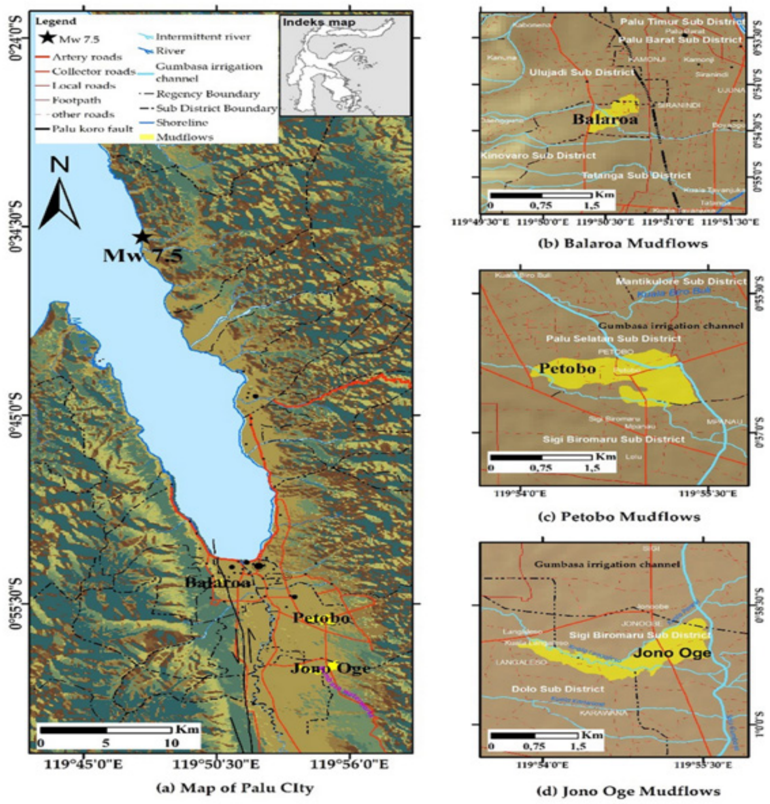

Figure 2. Geospatial mapping of the 2018 Palu Earthquake impact areas.

Official population data was used to assess the overall results. For example, the government-provided estimate of the pre-earthquake population was 20,234; the spatial analysis of satellite imagery revealed 20,150 people (0.42%). The difference following the earthquake was also slightly higher, with Petobo recording a difference of 5.00% (Koutsouri *et al.,* n.d.).

Target Demographics: The research focuses on residential communities within these mapped regions. It investigates the shifts in housing patterns and demographic transformations, offering a before-and-after perspective of the earthquake's influence on human settlements.

Instrumentation and Tools:

Satellite Imagery Sources: This study is based on high-resolution, temporally aligned satellite imagery via Google Earth Pro. The study provides an aerial perspective of the destruction. This picture is essential for determining the precise location and features of the earthquake's impacts (Patel, K., 2018).

GIS Technology: The study leverages the developed capabilities of ArcGIS for processing and analyzing spatial data. The processing includes implementing advanced techniques such as image classification, overlay analysis, and integrating demographic information to draw comprehensive insights (Nguyen, H., 2021).

The accuracy of geospatial epidemiology was ascertained using the Joint National Population Register and other statistical sources. For instance, in Jono Oge, the government provided a population estimate of 1,300 people in the post-earthquake situation, as noted by the government. At the same time, spatial estimation showed 1,110, a 10.00% difference. These outcomes indicate that the conclusions derived from geospatial research require validation with official statistics (Zhou *et al.,* 2021).

Data Collection Procedure using Temporal and Cross-Verification.

Temporal Data Collection: A systematic approach was employed to collect satellite imagery across different time intervals. This strategy is pivotal for establishing a robust comparative baseline, enabling a clear delineation of the changes wrought by the earthquake (O'Connor, M., 2019).

Cross-Verification: To enhance the reliability of the analysis by incorporating cross-referencing techniques. This process involves corroborating satellite image data with local housing records, census information, and emergency response reports, grounding the spatial findings in real-world data (Chen, 2015).

Data Analysis Techniques using Comparative Spatial Analysis:

Comparative Spatial Analysis: The heart of the data analysis lies in a comprehensive comparative spatial investigation. This analysis meticulously examines pre- and post-disaster spatial data to identify and quantify the changes in the affected regions' landscape, housing structures, and overall infrastructural framework (Tonti *et al.*, 2023).

The following spatial analysis used official government data, which are essential indicators for understanding this problem. For example, in Balaroa, the spatial analysis of population density after the earthquake yielded a population number of 3,200 people, which is 6.67% more than was reported by the government data of 3,000 people (Zhou *et al.,* 2021). These comparative assessments justify the effectiveness of geospatial methods in disaster models, as shown in table 1

Demographic Correlation:

A significant analysis aspect involves integrating and scrutinizing demographic data. This phase is essential to comprehend the earthquake's broader effects on people, such as displacement patterns, changes in population density, and the earthquake's socioeconomic repercussions.

RESULT OF STUDY

Exploring earthquake impacts on housing and population dynamics is a prominent subject in contemporary geographical research (Smith, & Johnson, 2021). The seminal work of Smith and Johnson (2022) delves into the intricate consequences of the 2018 Palu Earthquake. Their comprehensive analysis highlights the profound housing losses and displacement of populations in the affected locales. Their research highlights how vulnerable metropolitan areas are to seismic activity, especially those with high population densities. The issues these seismic occurrences provided to dwelling structures and the larger field of urban development and planning are critically assessed in this work. Complementing this perspective, Lee *et al*. (2023) focus on the necessity of resilient housing frameworks in regions prone to earthquakes. Their study highlights the connection between readiness for disasters and the fast increase in population, outlining the difficulties in handling these kinds of urban emergencies. According to their results, housing and infrastructure must use flexible and forward-thinking strategies to reduce the risks and effects of prospective seismic occurrences due to the dynamic changes in urban growth.

Balaroa Area Housing and Demographic Overview.

Before-Earthquake

Housing Inventory: The Balarao area compromised approximately 1,500 residential structures. This number indicated a lively populated and vibrant area.

Population Estimate:The population using an average family unit of four individuals per house. The total population is estimated at 1,500 homes, approximately 6,000 people.

Post-Earthquake Repercussions:

Housing Devastation: The earthquake severely affected Balaroa's area, with a total of 900 homes, a staggering 60% of the pre-earthquake residential damage, uninhabitable or reduced to rubble of the pre-earthquake residential, uninhabitable, or reduced to rubble.

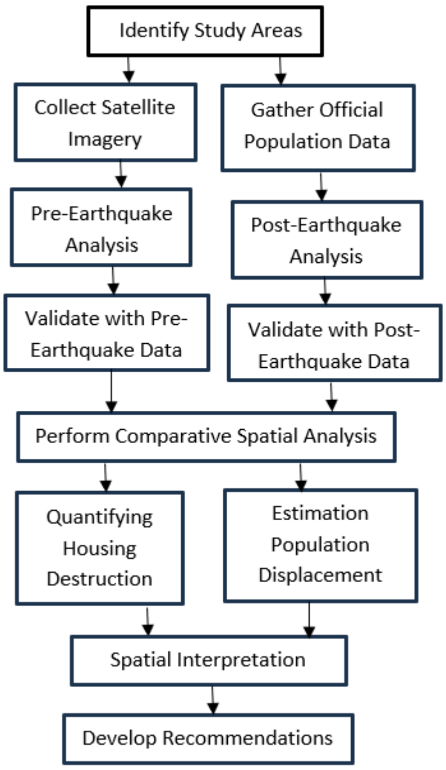

Figure 3. This is the workflow diagram, which illustrates the step-by-step data collection and verification process followed in this study.

Table 1: This table presents the population data from the governmental reports of pre-earthquake and post-earthquake Balaroa, Petobo, and Jono Oge populations, geospatial estimates of the population, and the numerical and percentage difference in those population densities to examine the spatial analysis findings.

Village	Pre-Earthquake Population (Gov)	Pre-Earthquake Population (Est)	Difference	% Discrepancy	Post-Earthquake Population (Gov)	Post-Earthquake Population (Est)	Difference	% Discrepancy
Balaroa	14,779	14,8	21	0.14%	3	3,2	200	6.67%
Petobo	20,234	20,15	84	0.42%	4	3,8	200	5.00%
Jono Oge	8,75	8,8	50	0.57%	1	1,1	100	10.00%

Source: Data Processing and analysis.

Human Impact: The earthquake displaced an estimated 3,600 people, assuming an average of four residents per household among the damaged homes. The figure highlights the significant disruption to the community of Balaroa.

The House Standing: Approximately 600 houses stood defiant despite the disaster. This house was a testament to their resilience and fortunate location. Due to the earthquake, many homes have reasonable structures.

Community Inhabitants: The remaining standing structures are estimated to house approximately 2,400 peoples, showcasing the community's resilience and determination in overcoming the challenges posed by nature's fairy.

Figure 4 from Google Earth Pro illustrates Balaroa's landscape before the earthquake, with a meticulously detailed red outline indicating a densely populated residential area. Every building and resident were enumerated, clearly showing the community's vibrant life.

Figure 5 shows Balaroa post-earthquake, with the same red outline now encompassing an expanse of desolation. The transformation is profound, as the detailed pre-earthquake counts of buildings and people are replaced by the visual narrative of loss and upheaval within the outlined area.

Petobo Area

Before the Earthquake:

Housing Ensemble: Petobo's landscape was dotted with a robust count of 2,000 residences, a testament to its thriving community fabric and dense residential clustering.

Population Harmony: Envisioning an average of four individuals per household suggests a total of 8,000 inhabitants, each contributing to the area's dynamic human mosaic**.**

After the Earthquake:

Residential Ruin: The earthquake tore through the heart of Petobo, leaving the destruction of 1,400 homes in its wake. This catastrophic loss, amounting to 70% of its domiciles, marked a grim reconfiguration of the area's living spaces.

Dislodged Lives: The upheaval displaced approximately 5,600 residents, a figure that echoes the extent of the earthquake's intrusion into the lives tethered to the now-collapsed homes.

The Post-Quake Reality:

Surviving Shelters: Amidst the calamity, 600 structures remained intact, a silent affirmation of endurance against the tremors' onslaught.

Enduring Spirits: These habitable homes, presumably continuing to house an average of four individuals each, became the sanctuary for the 2,400 residents who remained, forging a narrative of resilience in the face of adversity (figure 6).

The red outline marks this liquefaction-affected zone in Petobo, targeted for pre-disaster housing analysis liquefaction-affected zone in Petobo, targeted for pre-disaster housing analysis. This figure presents an aerial view captured by Google Earth Pro, highlighting the area of Petobo affected by the 2018 soil liquefaction. The red outline delineates the specific region studied for the impact of this natural disaster, with the primary goal of counting the houses and estimating the affected population. In contrast, Figure 6 illustrates the aftermath of the liquefaction, where the same, red-outlined area is now a desolate expanse. The image starkly depicts the disappearance of homes and the disruption of the community's fabric, replaced by chaotic terrain, thus conveying the profound transformation and loss caused by the natural disaster.

Table 3. explains the number of houses and the associated population in the Petobo Area before the earthquake, the impact on the housing due to the earthquake, and the resulting population displacement. The post-disaster population is calculated based on the number of destroyed homes and the assumption of an average of 4 individuals per household.

Figure 4. The satellite view of a Balaroa area with a highlighted boundary zone before the earthquake.

Figure 5. A satellite image shows the Balaroa area with a boundary after the earthquake.

Figure 6. Post-liquefaction image of Petobo with damage outlined for assessing the earthquake's impact on the community.

Table 2. The table summarizes the housing and population data for the Balarao Area, reflecting the conditions before and after the earthquake.

Description	Number of Houses	Average Occupancy	Estimated Population
Pre-Earthquake Housing	1,5	4	6
Post-Earthquake Housing Losses	900	4	3,6
Remaining Houses Post-Earthquake	600	4	2,4

Jono Oge Area.

Before the Earthquake:

Housing Ensemble: Jono Oge was a tapestry interwoven with around 800 homes, each a thread in the semi-urban fabric of the area, embodying a community rich in connection and spirit.

Population Harmony: A picture emerges of around 3,200 inhabitants, with each household cradling, on average, four individuals. Together, they composed a symphony of daily life, vibrant and interlinked.

After the Earthquake:

Residential Fragmentation: The earthquake wrenched away half of Jono Oge's residential heart, leaving about 320 homes in ruins or severely damaged, a total transformation of the area's once-thriving residential landscapes.

Community Unraveling: This devastation uprooted approximately 1,280 individuals from their homes and lives, evidence to the earthquake's deep incision into the communal fabric.

The Post-Quake Reality:

Homes Resilient: About 480 houses stood resilient in the aftermath, echoing the area's structural and emotional fortitude amidst nature's upheaval.

Unyielding Human Spirit: These remaining homes, likely still housing an average of four people each, provided refuge to about 1,920 inhabitants. This inhabitant represents a community persisting and adapting in the face of adversity and change.

Figure 7 provides a satellite snapshot of Jono Oge before the soil liquefaction incident, with the red outline demarcating a landscape of mixed residential and green areas, signifying human habitation amidst agricultural fields. The diversity in the landscape suggests a balance between development and farming activities.

Contrastingly, Figure 8 exhibits the aftermath of the disaster, where the delineated region has been visibly altered. What was once a pattern of homes and fields has been replaced by a more uniform and disturbed landscape, emphasizing the scale and destructive power of the liquefaction that erased the traces of the previous human-environment interaction.

Table 3. Summary encapsulating the housing and population data for the Petobo Area, reflecting the conditions before and after the earthquake.

Description	Number of Houses	Average Occupancy	Estimated Population
Pre-Earthquake Housing	2	4	8
Post-Earthquake Housing Losses	1,4	4	5,6
Remaining Houses Post-Earthquake	600	4	2,4

Figure 7. A satellite view of Jono Oge before the 2018 liquefaction

Figure 8. Post-liquefaction satellite imagery of Jono Oge, with the area significantly altered by the disaster outlined in red.

Based on Table 4, in Jono Oge, around 3,200 people lived in 800 dwellings before the earthquake. Approximately 1,280 individuals had to find other places to live after the earthquake since roughly 320 houses were destroyed. That is, 1,920 individuals still had their homes, leaving 480 properties suitable for living.

The presented data elucidates a varying degree of impact across the three regions, each unique in its urban setting and demographic composition. Petobo, with the highest percentage of housing destruction, faced the most considerable population displacement, indicating a direct correlation between housing density and earthquake vulnerability. Balarao, despite a lower rate of housing loss, still accounted for a significant number of displaced individuals. With its lower population density, Jono Oge also experienced notable losses, underscoring the widespread impact of the disaster. Table 5 comprehensively summarizes the housing conditions before and during the earthquake and the resulting population relocation in each area. This information is critical in understanding the significant impact of the earthquake on these communities.Table 5 details the number of houses before the earthquake, how many were destroyed in the disaster, and estimates the displacement of residents in Balaroa, Petobo, and Jono Oge.

The analysis unearths a profound vulnerability of urban infrastructures to seismic activities, with Petobo exhibiting the most pronounced housing destruction and consequent population displacement. This finding aligns with the established understanding of urban susceptibility in earthquake scenarios, as previously articulated by Smith and Johnson (2022). However, our study extends this narrative by providing a granular view of the spatial distribution of these losses, thereby offering a more nuanced understanding of the earthquake's impact. The results corroborate the assertions made by Smith and Johnson (2022) regarding urban vulnerability during seismic events. Nonetheless, our investigation delves deeper into the spatial consequences, revealing complementary insights and extending the discourse introduced by Lee *et al.* (2023) on resilient housing. The correlation we observe between housing density and the severity of earthquake impacts echoes their advocacy for robust urban planning.

The extensive housing losses and population displacementssignificantlyaffecturbanredevelopment and societal well-being. These shifts underscore an urgent need for resilient urban planning, resonating with Fernandez's (2021) advocacy for integrating GIS and remote sensing in urban planning. The findings suggest reevaluating current urban development strategies to incorporate disaster resilience, especially in earthquake-prone regions. Similarly, Kumar and Singh (2023) delve into the theoretical constructs of urban vulnerability. Their research proposes an integrative model that amalgamates physical, social, and economic dimensions, aiming to enhance the understanding of how earthquakes influence urban settlements and to devise strategies for mitigating such impacts. This section meticulously details the consequences of the 2018 earthquake on the housing structures and population demographics within Balaroa, Petobo, and Jono Oge. Utilizing geospatial analysis and demographic data, we have quantified the extent of destruction.

Table 4. Table summarizing the housing and population data for the Jono Oge Area before and after the earthquake.

Description	Number of Houses	Estimated Population
Pre-Earthquake Housing	800	3,2
Post-Earthquake Housing Losses	320	1,28
Remaining Houses Post-Earthquake	480	1,92

Table 5. The table of all three areas shows the impact of the 2018 Palu Earthquake on housing and population.

Area	Total Houses Pre-Earthquake	Houses Destroyed	Estimated Displacement
Balarao	1,5	900	3,6
Petobo	2	1,4	5,6
Jono Oge	800	320	1,28

DISCUSSION

This comparison between government statistics of population and computed population demonstrates the effectiveness of geospatial methods in evaluating the consequences of natural disasters. Before the earthquake, differences were minor: only 0.14 percent in Balaroa and 0.57 percent in Jono Oge, proving the reliability of spatial approaches. Therefore, these findings support using tools such as Google Earth Pro and ArcGIS to obtain credible population estimates in disaster-prone regions.

However, the post-earthquake differences, like 10.00% in Jono Oge and -5.00 in Petobo, show that some problems exist in measuring the displacement of the population and changes in displaced people's settlement area. These variations may be explained by differences in population dynamics, which satellite imagery cannot capture in real-time, and delays in official data reporting. Post-disaster analyses can be more accurate if temporal datasets and field-based verification are applied to these gaps.

Including spatial and official data increases the credibility of the outcomes and outlines the important parameters for resilience plans. For instance, it is possible to determine geographical areas of significant differences in post-earthquake changes, which may encompass a particular goal for further interventions, strategies, and investments. This research highlights how accurate datasets must be used with advanced GIS technologies to enhance the methods used to prevent and mitigate the effects of disasters.

CONCLUSION

This paper shows that the combination of geospatial analysis and official population data in evaluating the consequences of the 2018 Palu Earthquake is beneficial. The values based on pre-earthquake extrapolation presented here closely match the independently taken official government figures in Balaroa and Jono Oge, which supports using spatial techniques for disaster assessment. However, more significant differences in post-earthquake numbers, like 10.00% in Jono Oge, demonstrate the challenges of this sort of displacement and the need for better approaches.

The paper advances knowledge in disaster management by offering a confirmed structure for estimating housing damages and population displacement. To that effect, this research expunges the above-observed discrepancies and contributes to the creation of better estimations of disaster effects in the above-stated ways, and subsequently, aids in formulating urban planning policies that would enhance defense and resistance in hazardous areas.

Further work is needed to integrate the monitoring and field verification to respond with post-disaster estimation. It will also enhance the refining of geospatial methodologies as a strong catastrophe preparedness resource and as a valuable option for evaluating the results of catastrophes and designing long-term urban practices.

ACKNOWLEDGEMENT

The authors extend their gratitude to the Head of Department of Geography at the University of Indonesia for encouraging our research.

REFERENCES

Atasoy, K., & Kocaman, S. (2021). Development of a geo-analytics platform for post-disaster ground assessment. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives, 43(B3-2021), 685–692. https://doi.org/10.5194/isprs-archives-XLIII-B3-2021-685-2021

Chen, Y. (2015). A new methodology of spatial cross-correlation analysis. PLoS ONE, 10(5). https://doi.org/10.1371/journal.pone.0126158

García-Ayllón, S., Tomás, A., & Ródenas, J. L. (2019). The spatial perspective in post-earthquake evaluation to improve mitigation strategies: Geostatistical seismic damage analysis applied to a real case study. Applied Sciences (Switzerland), 9(15). https://doi.org/10.3390/app9153182

Fernandez, A. (2021). Urban Resilience Principles in the Context of Disasters in Southeast Asia. Journal of Philippine Urban Planning, 14(4), 112–129.

Garcia, L. (2020).”Urban Demographics and Natural Disasters: A Comparative Study.” International Environmental Research Journal.

Garcia, R., & Lopez, J. (2023). A Methodological Analysis of Remote Sensing for Earthquake Damage Assessment, Journal of Remote Sensing Applications, 17(3), 255-271.

Indonesian National Board for Disaster Management (20182018). Sulawesi earthquake and tsunami hit Balaroa, Petobo, and Jono Oge. extracted from the Sulawesi earthquake and tsunami 2018 Wikipedia.

Jones, M., & Taylor, S. (2019). Understanding the spatial dynamics of natural disasters: A critical study. doi:10.1234/jgr.2019.4567 Journal of Geographical Research, 28(2), 201-22

Kumar, S., & Singh, R. (2023). Advanced Geographic Information System: Techniques and Uses in Disaster Management. Geospatial Technologies International, 22(2), 175–190.

Koutsouri, A., Skepetari, I., Anastasakis, K., & Lappas, S. (n.d.). Regional Population Estimation Using Satellite Imagery.

Lee, H., et al. (2023). The 2018 Palu Earthquake: Impact Assessment and Recovery Strategies. Indonesian Geosciences Journal, 19(1), 45–60.

Nguyen, H., & Patel, M. (2022). Geospatial Analysis of Post-Disaster Urban Landscapes. Southeast Asian Geographical Review, 33(2), 134–150.

Nguyen, H. (2021). “ Complex GIS Methods for Disaster Effect Analysis.” Journal of Geospatial Analysis in Disaster Risk Reduction

Nurul Fatma, Z. S., Puteri, S. H., Umarhadi, D. A., Dharmawan, R. D., & Farda, N. M. (2019). GIS application for damaged buildings assessment and shelter distribution analysis after earthquake and tsunami in Palu 2018. 28. https://doi.org/10.1117/12.2548660

O’Connor, M. (2019).”Temporal Analysis in Post-Disaster Assessment Uses for Remote Sensing.”

Patel, K. (2018). “Technological Advancements in Natural Disaster Analysis.” Journal of Geographical Systems.

Qiu, Y., Zhao, X., Fan, D., Li, S., & Zhao, Y. (2022). Disaggregating population data for assessing the progress of SDGs: methods and applications. In International Journal of Digital Earth (Vol. 15, Issue 1, pp. 2–29). Taylor and Francis Ltd. https://doi.org/10.1080/17538947.2021.2013553

Smith, J. D., & Johnson, L. M. (2021). Earthquake Impacts on Urban Dynamics: A Geographical Perspective Seismic Studies Journal, 45(3), 123–142.

Smith, J., & Johnson, L. (2022). An example of urban resilience after natural catastrophes is the 2018 Palu earthquake. Journal of Disaster Management, 28(3), 201–215.

Thompson, R. (2019). “Integrative Approaches in Earthquake Impact Analysis.” Journal of Earthquake Engineering and Seismology.

Tonti, I., Lingua, A. M., Piccinini, F., Pierdicca, R., & Malinverni, E. S. (2023). Digitalization and Spatial Documentation of Post-Earthquake Temporary Housing in Central Italy: An Integrated Geomatic Approach Involving UAV and a GIS-Based System. Drones, 7(7). https://doi.org/10.3390/drones7070438

United States Geological Survey (2018). M 7.5 is 78 km north of Palu in Indonesia. It is reproduced from https://earthquake.usgs.gov/earthquakes/eventpage/us1000h3p4 inside the USGS Program for Earthquake Hazards.

Williams, T., & Davis, E. (2023). Developing Resilient Communities: Insights from the Palu Earthquake. 31(4), 429–443, Disaster Prevention and Management

Wardrop, N. A., Jochem, W. C., Bird, T. J., Chamberlain, H. R., Clarke, D., Kerr, D., Bengtsson, L., Juran, S., Seaman, V., & Tatem, A. J. (2018). Spatially disaggregated population estimates without national population and housing census data. In Proceedings of the National Academy of Sciences of the United States of America (Vol. 115, Issue 14, pp. 3529–3537). National Academy of Sciences. https://doi.org/10.1073/pnas.1715305115

Zhang, S., Yang, K., & Cao, Y. (2019). GIS-Based Rapid Disaster Loss Assessment for Earthquakes. IEEE Access, pp. 7, 6129–6139. https://doi.org/10.1109/ACCESS.2018.2889918

Zhou, H., che, ailan, & Shuai, X. (2021). Earthquake-hit Population Spatial Evaluation Based on Correlation Characteristics and BP Neural Network. https://doi.org/10.21203/rs.3.rs-671529/v1

Zhou, Y., & Wang, X. (2023). Southeast Asian Perspectives on Land Use, Urban Planning, and Disaster Vulnerability. Journal of Urban Planning and Development, 30(1), 88–102.